

Transmission of Gastrointestinal Parasites in Dairy Calves on Pasture in Central Kentucky from 1987 through 1989¹

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ABSTRACT: Parasite-naïve tester dairy calves ($N = 50$) were placed on helminth-infested pasture once a month (1–3 calves) for 1 mo during the period July 1987–November 1989 (except for January 1989). At necropsy, the predominant mature parasites and mean numbers recovered from the tester calves were *Ostertagia ostertagi*—703, *Nematodirus helvetianus*—1,626, *Cooperia oncophora*—3,401, and *Trichuris* spp. (includes immatures)—138. The average total number of these parasites per calf was 5,885, with the highest monthly values found in July for 1987, April for 1988, and June for 1989. For each of these parasites, the month (each year) with the maximal numbers of mature specimens was: *O. ostertagi* in July 1987, May 1988, and June 1989; *N. helvetianus* in October 1987, May 1988, and June 1989; *C. oncophora* in July 1987, April 1988, and June 1989; *Trichuris* spp. (includes immatures) in August 1987, May 1988, and August 1989.

Ostertagia ostertagi L₄ were found only in November 1987, April and May 1988, and June, September, and October 1989; the average numbers were low, varying from 20 to 170. Low numbers of L₄ *N. helvetianus* and *C. oncophora* were present also in calves in several months. Other parasites present were *Moniezia* spp. (1–31 specimens each) in 17 calves and *Bunostomum phlebotomum* (3 specimens) in 1 calf. The eyeworm, *Thelazia gulosa*, was found (1–7 specimens per calf) in 6 calves.

KEY WORDS: internal parasites, natural infections, transmission, dairy calves, Kentucky.

Transmission of internal parasites of cattle has been studied extensively in many parts of the world. A review of epizootiology of nematodes of cattle in North America has been published recently (Williams, 1986). Studies on transmission of helminths of cattle in central Kentucky have been minimal; mainly they have been on overwintering of internal parasites (Drudge et al., 1958; Lyons et al., 1983).

The purpose of the present research was to obtain information on the seasonal transmission pattern of internal parasites of dairy calves on a farm in central Kentucky, with special interest in observing hypobiosis of *Ostertagia*.

Materials and Methods

A total of 50 calves (28 Jerseys and 22 Holsteins) was obtained from a local dairy farm. Sexes of the calves were 46 males (intact) and 4 females. They were raised parasite-free after being removed from their dams at about 2–4 days of age. Until weaning, they were fed a commercial milk replacer and a supplemental grain ration. They eventually accepted a complete pelleted ration which was fed during the remaining periods of confinement. The calves were kept individually in wire-bottom cages, situated in separate rooms, during pre- and postpasture exposure periods. Cages, food and

water containers, and areas surrounding the cages, including the floor and walls, were washed twice daily.

From July 1987 through November 1989 (except for January 1989), 1–3 calves (designated as “testers”) per month, at about 60–180 days of age, were placed on pasture. Data for the months of May–November 1989 are evaluated cautiously because only 1 tester calf was examined for each of these months.

The tester calves were located on pastures grazed concurrently by older dairy cattle naturally infected with internal parasites. These nontester cattle on pasture were mostly yearlings, but some were younger; numbers varied from about 6–35. Anthelmintic therapy for them consisted of 2 treatments (spring and fall) each year with levamisole.

Tester calves were kept on pasture for a 1-mo period, and then returned to confinement in individual cages. They were held in these cages for an additional month to allow time for advanced development or maturation of the parasites to occur. The testers were then killed and the gastrointestinal tracts were examined for internal parasites. Also, the eyes were examined for eye-worms except for July 1987 and December 1987–April 1988. Fecal samples were collected from the rectum of each calf at necropsy for epg (worm eggs per gram of feces).

Processing of the gastrointestinal tract included 2 ligatures: at the junctions between the abomasum and duodenum and between the ileum and cecum. Contents of the 3 portions—the abomasum, the small intestine, and the combination of cecum and large intestine—were expressed into separate containers. Then, the various segments of the tract were flushed 3 times with water to rinse out remaining particulate material and parasites. Rinses were added to the appropriate containers of contents. The 3 portions (abomasum,

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Table 1. Worm data for tester calves (*N* = 12) at necropsy in 1987.

Tester calves		No. of parasites for individual calves							
		<i>Ostertagia ostertagi</i>		<i>Nematodirus helvetianus</i>		<i>Cooperia oncophora</i>		<i>Trichuris</i> * spp.	Total
Month on pasture	No.	Imm	Mat	Imm	Mat	Imm	Mat		
July	2	0	480	20	2,640	20	9,320	269	12,749
		0	840	20	1,180	20	14,300	88	16,448
August	2	0	220	0	1,780	0	4,460	176	6,536
		0	300	80	2,300	20	8,080	286	11,066
September	2	0	40	60	3,660	0	780	245	4,785
		0	100	120	5,020	0	1,400	136	6,776
October	2	0	80	60	4,720	0	660	14	5,534
		0	20	20	5,980	0	640	42	6,702
November	2	80	60	40	680	0	300	40	1,200
		100	40	60	1,980	0	360	0	2,540
December	2	0	40	0	220	20	100	109	489
		0	60	0	100	20	420	3	603
Aggregate average		15	190	40	2,522	8	3,402	118	6,294

* Stages not determined.

Imm = immature; Mat = mature.

small intestine, and cecum-large intestine) of the gastrointestinal tract were cut open and any observed parasites were removed and saved. Each section of the tract was then suspended, with large paper clips, in containers of water (1-gallon each for the abomasum and for the cecum-large intestine and 2.5 gallons for the small intestine) for about 6 hr to permit migration of parasitic stages from the mucosa (Williams et al., 1979). Afterwards, the walls of the tract were rubbed (Williams et al., 1979) by hand under tap water into a 200-mesh sieve. The residue, along with the water and materials in the containers in which the tissues had been suspended, were washed on the 200-mesh sieve; the residue was saved and preserved with 5% formalin. Artificial digestive juice was not used for parasite recovery from any portions of the gastrointestinal tract. Further processing of all of the material for recovery of parasites was similar to that published previously (Drudge et al., 1963). Basically, it included washing aliquot samples (50 ml/liter) of fixed material from the abomasum and intestine onto 100-mesh (contents and washes) or 200-mesh ("soaks" of tissue) sieves. The residue from the samples was examined for worms through a stereoscopic microscope at about 10×. After sampling, excess material was washed onto a 40-mesh sieve and the remains were examined grossly for larger parasites. Procedures for recovery of eyeworms (Lyons and Drudge, 1975) and for determining epg were likewise as described previously (Drudge et al., 1963).

Results and Discussion

Four main genera (*Ostertagia*, *Nematodirus*, *Cooperia*, and *Trichuris*) of internal parasites were recovered at necropsy from the tester calves (Tables 1–3). Species of these genera include *Ostertagia ostertagi* from the abomasum, *Nematodi-*

rus helvetianus and *Cooperia oncophora* from the small intestine, and *Trichuris* spp. from the cecum-large intestine. They are the same species predominating in the same dairy herd in past research (Lyons et al., 1983).

For each year the highest monthly mean number of mature *O. ostertagi* was in July (660) for 1987, May (5,400) for 1988, and June (2,620) for 1989. The total numbers ranged from 0 in February and November 1988, and November 1989, to 6,320 in May 1988. The numbers generally declined in the months after the highest values, except for moderate increases in September and October for both 1988 and 1989.

For mature *N. helvetianus*, the highest average numbers were in October 1987 (5,350), May 1988 (3,390), and June 1989 (9,440). The total numbers of this parasite varied from a low of 0 for 5 months (February and December 1988 and February, March, and November 1989) to a high of 9,440 for 1 month (June 1989). Numbers were generally much lower by 1–2 mo after the highest values. The decline was over a longer period though for 1989.

Mature *C. oncophora* were present in highest average numbers in July 1987 (11,810), April 1988 (30,440), and June 1989 (7,780). The total numbers varied from a low of 0 (February 1988 and November 1989) to a high of 37,100 (April 1988). After the month with the highest numbers, a gradual decrease was evident in the succeeding months in 1987. This same pattern oc-

Table 2. Worm data for tester calves ($N = 25$) at necropsy in 1988.

Tester calves		No. of parasites for individual calves							Total
		<i>Ostertagia ostertagi</i>		<i>Nematodirus helvetianus</i>		<i>Cooperia oncophora</i>		<i>Trichuris</i> * spp.	
Month on pasture	No.	Imm	Mat	Imm	Mat	Imm	Mat		
January	3	0	220	0	120	0	360	2	702
		0	200	20	300	0	920	3	1,443
		0	340	105	585	0	1,185	40	2,255
February	2	0	0	0	0	0	0	2	2
		0	0	0	20	0	0	8	28
March	2	0	120	0	100	0	60	20	300
		0	210	0	220	0	750	19	1,199
April	2	60	2,440	0	700	20	23,780	16	27,016
		80	4,320	220	100	640	37,100	20	42,480
May	2	0	6,320	0	1,600	0	10,020	219	18,159
		340	4,480	200	5,180	0	16,020	106	26,326
June	2	0	220	20	2,320	0	300	112	2,972
		0	200	80	4,013	0	560	135	4,988
July	2	0	180	20	500	0	300	27	1,027
		0	140	40	1,860	0	700	113	2,853
August	2	0	280	100	100	0	640	27	1,147
		0	260	80	1,060	0	700	79	2,179
September	2	0	380	0	160	0	1,720	10	2,270
		0	540	0	340	0	2,440	77	3,397
October	2	0	240	0	60	0	1,460	59	1,819
		0	320	0	60	20	2,100	132	2,632
November	2	0	0	0	20	0	140	20	180
		0	40	0	40	0	280	40	400
December	2	0	115	0	15	0	655	32	817
		0	280	0	0	0	750	16	1,046
Aggregate average		19	874	35	779	27	4,118	53	5,905

* Stages not determined.

Imm = immature; Mat = mature.

curred in 1988, except for a rebound during September and October. For 1989, the postpeak decline was relatively less than observed for the other years, but there was a repetition of 1988 in the increase in numbers in September and October.

For *Trichuris* spp. (mature and immature), the months with the highest average numbers per calf were August 1987 (231), May 1988 (163), and August 1989 (1,479). The total numbers varied from a low of 0 (November 1987 and February and March 1989) to a high of 1,479 (August 1989). Numbers of specimens were quite variable for most of the months following the peak periods.

Immature forms of *O. ostertagi* (L₄) were found in low numbers (20–340 per calf) in only 8 calves during 6 mo (November 1987, April and May 1988, and June, September, and October 1989). Measurements of L₄ specimens indicated all were

≤2.0 mm long except for 2 (2.5 mm and 3.8 mm long).

For L₄ *N. helvetianus*, low numbers (20–260) were recovered from about one-half (26) of the calves. The highest average numbers of L₄ *N. helvetianus* (1.3–7.0 mm long) per calf were in September 1987 (90), April 1988 (110), and June 1989 (260). *Cooperia oncophora* L₄ (20–640) were present in only 12 calves; the highest numbers (640) were in April 1988 (all were ≤2.5 mm long, except 1 which measured 6.0 mm long).

For all stages of the 4 predominant genera (*Ostertagia*, *Nematodirus*, *Cooperia*, and *Trichuris*) in the tester calves, the month with the highest average number was July 1987 (14,599), April 1988 (34,748), and June 1989 (20,520). For the entire study, the aggregate mean number of these 4 genera per calf was 6,294 in 1987, 5,905 in 1988, and 5,465 in 1989. This value for all 50 calves was 5,885.

Table 3. Worm data for tester calves (N = 13) at necropsy in 1989.

Tester calves		No. of parasites for individual calves							
		<i>Ostertagia ostertagi</i>		<i>Nematodirus helvetianus</i>		<i>Cooperia oncophora</i>		<i>Trichostrongylus</i> * spp.	Total
Month on pasture	No.	Imm	Mat	Imm	Mat	Imm	Mat		
February	2	0	140	0	0	0	60	21	221
		0	380	0	0	0	120	0	500
March	2	0	440	0	0	20	340	0	800
		0	440	0	20	0	360	61	881
April	2	0	1,500	20	620	0	1,060	750	3,950
		0	1,200	20	2,680	0	1,160	45	5,105
May	1	0	360	0	860	0	380	865	2,465
June	1	20	2,620	260	9,440	0	7,780	400	20,520
July	1	0	920	100	6,760	20	3,800	206	11,806
August	1	0	660	40	1,960	20	1,440	1,479	5,599
September	1	20	1,180	40	3,000	0	4,460	186	8,886
October	1	20	1,160	160	3,520	20	5,280	150	10,310
November	1	0	0	0	0	0	0	2	2
Aggregate average		5	846	49	2,220	6	2,018	320	5,465

* Stages not determined.
Imm = immature; Mat = mature.

Other helminths were also recovered from the tester calves, but the data are not presented in tabular form. *Moniezia* spp. were found in 17 calves (1–31 specimens each) in July through October 1987, in April through October 1988, and in April 1989. *Bunostomum phlebotomum* were found in 1 calf (3 specimens) in September 1988. The eyeworm, *Thelazia gulosa*, was recovered from 6 calves (1–7 specimens each) in August and September 1987 and in June, August, and September 1988.

Trichostrongyle epg data are recorded (Table 4). The epg values generally had similar patterns observed for the worm counts.

All of the parasites except *B. phlebotomum* had been found previously in the dairy herd used for the present study (Lyons et al., 1981a, b, 1983). However, only in 1 earlier study had the small and large intestine been examined for parasites (Lyons et al., 1983). Gastrointestinal parasites found in the herd in the past but not present research were *Trichostrongylus axei* and *Haemonchus* spp. (Lyons et al., 1981a). Other internal parasites recovered from calves in additional herds in this geographical area are *Cooperia punctata*, *Oesophagostomum radiatum*, and *Strongyloides papillosus* (Lyons et al., 1972, 1982).

Establishment of a seasonal inhibition pattern or hypobiosis of *L*₄ *O. ostertagi*, *N. helvetianus*, and *C. oncophora* in this geographical area was

not revealed in the present observations because of generally low numbers recovered. It is unfortunate that the numbers of *L*₄ were so low, because the present study does not clarify the inhibition pattern of *O. ostertagi*, in particular, in cattle in central Kentucky. Also, the numbers of mature *O. ostertagi* were not high. This indicates that nontester cattle were not shedding many *O. ostertagi* eggs on pasture. Therefore, few larvae of the parasites were available for ingestion by tester calves. Possibly, the numbers of *L*₄ trichostrongyles might have been higher if recovery methods from the gastrointestinal tract had been for a longer time, e.g., 24 hr (Williams et al., 1981; Gasbarre, 1987) instead of 6 hr (Williams et al., 1979). Also, the size of the sieve openings (200 mesh) may have been too large for maximum retention of *L*₄ during washing of material.

The nonimmune state of the tester calves, because of a lack of previous exposure to *Ostertagia* and other parasites, may have been a factor in low numbers of *L*₄. Supporting this view is research by Michel (1970), showing that the numbers of inhibited *Ostertagia* were higher, in previously infected, than naive calves. However, Anderson (1988) states that seasonal inhibition of *Ostertagia* occurred in both naive and previously infected calves. Another view on hypobiosis is that it is due to environmental factors (Williams, 1986).

It seems clear that if much higher numbers of

Table 4. Worm eggs per gram of feces (epg) for tester calves ($N = 50$) at necropsy in 1987 ($N = 12$), 1988 ($N = 25$), and 1989 ($N = 13$).

Month on pasture	Total no.*	Epg for individual calves								
		Trichostrongyle†			Nematodirus			Total		
		1987	1988	1989	1987	1988	1989	1987	1988	1989
January	3	—	60	—	—	0	—	—	60	—
		—	20	—	—	0	—	—	20	—
		—	30	—	—	10	—	—	40	—
February	4	—	0	60	—	0	0	—	0	60
		—	0	10	—	0	0	—	0	10
March	4	—	20	20	—	0	0	—	20	20
		—	60	40	—	0	0	—	60	40
April	4	—	90	180	—	0	0	—	90	180
		—	1,350	160	—	0	0	—	1,350	160
May	3	—	1,040	50	—	40	0	—	1,080	50
		—	1,110	—	—	10	—	—	1,120	—
June	3	—	60	150	—	20	30	—	80	180
		—	0	—	—	10	—	—	10	—
July	5	810	70	590	30	0	120	840	70	710
		1,010	30	—	90	10	—	1,100	40	—
August	5	150	20	30	60	0	20	210	20	50
		310	110	—	10	0	—	320	110	—
September	5	70	230	450	70	0	40	140	230	490
		90	60	—	60	0	—	150	60	—
October	5	0	180	70	30	0	0	30	180	70
		20	110	—	40	0	—	60	110	—
November	5	20	10	0	40	0	10	60	10	10
		30	10	—	30	0	—	60	10	—
December	4	0	90	—	0	0	—	0	90	—
		0	30	—	0	0	—	0	30	—
Aggregate average		209	192	139	38	4	17	248	196	156

* Total number of calves examined for each month for all 3 years; the number of calves examined for each month for individual years can be obtained by counting the total number of epg values for each time period.

† Excluding *Nematodirus*.

L_4 nematodes had been on pasture, the tester calves would have had greater levels of parasites, allowing more meaningful interpretation of seasonal transmission, including inhibition of these parasites. Further research is necessary to establish the inhibition phenomenon of larval nematodes in central Kentucky.

Regarding mature specimens of *Ostertagia*, *Nematodirus*, and *Cooperia*, the time of the year (April, May, and/or June in 1988 and 1989), with the highest numbers present, were similar. *Trichostrongylus* spp., although found in all months of the study, were most numerous in 1989. The total numbers of all stages of the 4 main genera of gastrointestinal parasites followed a similar pattern (1988 and 1989) of being most prevalent in the spring, summer, and fall months (April–October). There were fewer total parasites recov-

ered from the calves in June and July 1988 than for a comparable time in 1989 and July in 1987. Possibly, this was because of a drought in 1988, particularly in June and early July (Table 5). However, in 1987 a drought occurred in August, September, and October (Table 5) and values for total parasites were higher than in 1988, but similar to those in 1989.

It is of interest that transmission of the parasites from pasture to calves occurred in varying degrees year-round. Lower numbers of parasites in calves in the coldest months may have been partially the result of these animals preferring to eat hay, rather than graze the poor quality vegetation on pasture at that time of the year. Previously it was determined in tester calves that several species of helminths (*O. ostertagi*, *T. axei*, *N. helvetianus*, *Nematodirus* spp., *C. oncophora*,

Table 5. Climatological data* for 1987, 1988, and 1989 for the vicinity of pasture used for the parasite transmission study.

Date	Temperature (F°)			Precipitation (inches)
	Minimum	Maximum	(Av)	
1987				
January	7	59	(34)	1.20
February	14	58	(40)	4.15
March	23	76	(49)	3.43
April	30	84	(55)	2.40
May	40	91	(71)	1.70
June	53	92	(76)	5.96
July	56	95	(78)	2.95
August	53	97	(77)	0.77
September	42	89	(70)	0.92
October	25	80	(53)	0.52
November	15	83	(51)	3.32
December	16	66	(39)	6.28
Total	—	—	—	33.60
1988				
January	−3	64	(31)	3.68
February	−1	67	(34)	3.37
March	18	78	(45)	2.12
April	28	88	(54)	3.78
May	36	90	(63)	2.55
June	39	100	(72)	0.55
July	46	103	(78)	3.87
August	47	100	(78)	3.41
September	42	87	(68)	4.94
October	22	76	(50)	1.81
November	23	72	(47)	6.08
December	6	66	(37)	3.76
Total	—	—	—	39.92
1989				
January	16	69	(40)	3.71
February	3	65	(33)	9.85
March	18	80	(48)	7.09
April	20	85	(54)	3.19
May	31	88	(61)	4.97
June	48	92	(72)	5.68
July	53	93	(76)	3.85
August	46	91	(74)	3.89
September	33	89	(67)	4.12
October	28	84	(56)	2.90
November	17	73	(45)	2.89
December	−20	59	(23)	1.80
Total	—	—	—	53.94

* Data were obtained from the University of Kentucky weather station, located on Spindletop Farm about 1 mile from the parasite study area. They were supplied by K. T. Priddy, Department of Agricultural Engineering, University of Kentucky.

Trichuris spp., *Moniezia* spp., and *Dictyocaulus viviparus*) overwinter on pasture in central Kentucky (Drudge et al., 1958; Lyons et al., 1981a, 1983).

From the present investigation, a seasonal pat-

tern of greatest transmission of the 3 most prevalent genera of mature gastrointestinal parasites, found in cattle during this study in central Kentucky, was defined as during the spring months.

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Literature Cited

Anderson, N. 1988. Aspects of the biology of *Ostertagia ostertagi* in relation to the genesis of ostertagiasis. *Veterinary Parasitology* 27:13–21.

Drudge, J. H., S. E. Leland, Z. N. Wyant, and J. W. Rust. 1958. Winter survival of some cattle parasites on Kentucky pasture with observations on the effects of low-level phenothiazine treatment. *Journal of Parasitology* 44:434–438.

—, J. Szanto, Z. N. Wyant, and G. Elam. 1963. Controlled test of the anthelmintic activity of thia-bendazole and an organic phosphate (CI 38,023) in lambs. *American Journal of Veterinary Research* 24:337–342.

Gasbarre, L. C. 1987. Recovery of third-stage larvae of *Ostertagia ostertagi* from the abomasa of experimentally inoculated calves by prolonged saline incubation. *Proceedings of the Helminthological Society of Washington* 54:160–161.

Lyons, E. T., and J. H. Drudge. 1975. Two eye-worms, *Thelazia gulosa* and *Thelazia skrjabini* in cattle in Kentucky. *Journal of Parasitology* 61: 1119–1122.

—, D. E. LaBore, and S. C. Tolliver. 1972. Field and controlled test evaluations of levamisole against natural infections of gastrointestinal nematodes and lungworms in calves. *American Journal of Veterinary Research* 33:65–71.

—, S. C. Tolliver, R. W. Hemken, and F. S. Button, Jr. 1983. Further tests of activity of levamisole on *Ostertagia ostertagi* in dairy calves with notes on overwinter survival of gastrointestinal helminths on pasture. *American Journal of Veterinary Research* 44:1760–1762.

—, R. W. Hemken, and F. S. Button, Jr. 1981a. Overwintering of larvae of the cattle lungworm (*Dictyocaulus viviparus*) on pasture in Kentucky. *Journal of American Veterinary Medical Association* 179:456–457.

—, S. C. Tolliver, and J. H. Drudge. 1982. Controlled test of the efficacy of a feed premix formulation of crufomate on the parasites of the gastrointestinal tract and lungs of dairy calves. *American Journal of Veterinary Research* 43:1072–1074.

—, —, —, R. W. Hemken, and F. S. Button, Jr. 1981b. Efficacy of levamisole against abomasal nematodes and lungworms in dairy calves. Preliminary tests indicating reduced activity of *Ostertagia ostertagi*. *American Journal of Veterinary Research* 42:1228–1230.

- Michel, J. F.** 1970. The regulation of populations of *Ostertagia ostertagi* in calves. *Parasitology* 61:435–447.
- Williams, J. C.** 1986. Epidemiologic patterns of nematodiasis in cattle. Pages 235–246 in H. C. Gibbs, R. P. Herd, and K. D. Murrell, eds. *The Veterinary Clinics of North America*. W. B. Saunders Co., Philadelphia.
- , **J. W. Knox, B. A. Baumann, T. G. Snider, and T. J. Hoerner.** 1981. Anthelmintic efficacy of albendazole against inhibited larvae of *Ostertagia ostertagi*. *American Journal of Veterinary Research* 42:318–321.
- , ———, **D. W. Sheehan, and R. H. Fuselier.** 1979. Activity of fenbendazole against inhibited early fourth-stage larvae of *Ostertagia ostertagi*. *American Journal of Veterinary Research* 40:1087–1090.

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